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Method for Improving Driving Stability

The present invention relates to a method of increasing driving stability in motor vehicles during controlled braking operations according to the preamble of claim 1 and an electronic motor vehicle brake system according to claim 5.

Especially an improved pressure control for preventing locking of the rear axle in electronic motor vehicle brake systems for vehicles with coupled rear wheels is described, said rear wheels comprising a per se known yaw torque control (YTC) in addition to ABS. A yaw torque control system becomes active when a vehicle is moving on roadways with so-called µ-split conditions, implying that with µ-split conditions different coefficients of friction act on the wheels causing yaw torque that acts on the vehicle.

Apart from the objective of achieving an optimal stopping distance, another objective in a conventional motor vehicle anti-lock system is to safeguard a driving behavior as stable as possible when performing wheel slip control, while renouncing an optimal stopping distance. Therefore, the rear axle in passenger cars is usually controlled according to the 'select-low' principle. The 'select-low' principle is characterized in that the brake pressure on both rear wheels is determined by the rear wheel having the stronger tendency to lock. This condition safeguards maximum vehicle stability.

An object of the invention is to improve a per se known ABS control method for vehicles with coupled rear wheels (e.g. rigid coupling).

According to the invention, this object is achieved by a method according to patent claim 1.

It has shown that the 'select-low' principle in vehicles whose rear wheels are e.g. coupled rigidly by way of a locked differential causes an unstable driving behavior above all on roadways with different coefficients of friction.

Among others, the invention is based on the knowledge that the rigid coupling of the rear wheels in connection with the 'select-low' principle brings about that the sum of the respectively maximum longitudinal force that can be transmitted by the rear wheels is subdivided in equal shares between both rear wheels.

The term 'rigid coupling' implies a permanently prevailing or a detachable rigid coupling of the wheels of the rear axle, and the term 'rigid' also includes, at least to a certain extent, elastic or yielding coupling engagements.

The invention discloses a special pressure modulation method for the rear axle, and this special pressure modulation is performed on the rear axle in that the pressure modulation of the front wheel being at a low coefficient of friction is adopted for both wheels of the rear axle without substantial changes.

Due to the rigid coupling of the rear wheels, the almost identical wheel behavior of both rear wheels does not allow concluding the brake pressure at the adhesion limit of one

wheel but only the *sum* of the brake pressures at the adhesion limit of both rear wheels. As the front wheels are not coupled, it is possible to infer the brake pressure at the adhesion limit of one wheel from the behavior of the front wheels. For this reason, the pressure modulation of the front wheel having a low coefficient of friction is adopted for the rear axle.

In a particularly suitable manner, the special pressure modulation method proposed herein can be supplemented in combination with a per se known YTC method. A YTC method during an ABS control operation is used to reduce the yaw torque by means of brake pressure modulation at the front axle especially when 'µ-split' roadways are detected.

Consequently, the method of the invention serves to increase driving stability on 'µ-split' roadways in vehicles with rigidly coupled rear wheels compared to per se known methods.

In a preferred fashion, further detection mechanisms to avoid slip on the rear axle can be activated in parallel, which have the effect that pressure on both rear wheels is reduced when an imminent unstable wheel behavior is detected on at least one rear wheel.

The special pressure modulation on the rear axle according to the invention is preferably made dependent on a detection signal signaling whether coupling of the rear wheels prevails. It is furthermore suitable to make the function dependent on the issue whether the YTC function on the front axle is active. It is especially expedient when, as a criterion of detecting a 'µ-split' roadway, it is monitored whether a YTC function provided in the control unit is currently active.

The pressure increase times and pressure reduction times adopted for the rear axle from the front wheel having a low coefficient of friction, admittedly, are adopted without substantial changes, yet can be weighted slightly differently in the sense of the invention. Discrepancies are generally limited to the effect of compensating possibly existing hydraulic differences (e.g. volume absorption, line cross-section, switching orifice) in the brake circuit of the front and rear axles. Preferably, the front wheel having a low coefficient of friction is detected by making a check whether an active YTC function on this wheel does not intervene in the current situation.

Further preferred embodiments can be taken from the sub claims and the following description of the Figures.

The invention is explained in detail in the following by way of examples.

In the drawings:

Figure 1 shows an illustration of driving parameters during an ABS controlled braking operation with a 'select-low' control on the rear axle 'μ-split' roadway;

Figure 2 shows a corresponding illustration of these driving parameters after the method of the invention has been implemented.

Referring to Figures 1 and 2, the vehicle reference speeds v_{ref1} to v_{ref4} (derived from v_{ref}) have been plotted against time t jointly with the wheel speeds (v_{e11} to v_{e14}) of the individual vehicle wheels for the wheels 1 to 4. The wheels 'left front', 'right front', 'left rear', and 'right rear' have generally

been designated numerals 1 to 4. Further, the yaw rate FYAWRATE and the current steering angle FSTANGLE of the vehicle are plotted as a function of time t. The curves V_{alti1} to V_{alti4} indicate the time variation of the condition of the inlet and outlet valve for the wheels 1 to 4 adjusted by the control unit. The curves VR_p, VL_p, HR_p and HL_p represent the currently prevailing pressure in the corresponding wheel cylinders.

It becomes apparent from Figure 1 that during an ABS braking operation on µ-split the wheel speed v_{el1} of wheel 1 (left front) drops below the vehicle reference speed. In the further course of time, during an activated ABS control, the wheel speeds of the two rear wheels v_{el3} and v_{el4} drop to a value below the reference speed V_{ref}. In consequence thereof, the rear wheels can transmit only a small amount of lateral force onto the roadway. The vehicle becomes unstable. In addition, the YTC function of the ABS control unit builds up a yaw torque acting on the vehicle on the front axle, what causes swerving of the vehicle, as can be seen from the course of the curves of the yaw rate FYAWRATE and from the steering angle FSTANGLE influenced by the driver.

Figure 2 shows an ABS-controlled braking operation that is supplemented by the method of the present invention. The curve V_{alti1} shows the actuation signals of the front wheel 'left front', which has a lower coefficient of friction than the front wheel ,right front'. The pressure reduction on the front wheel ,right front' is therefore lower, as can be seen from curve V_{alti2}. Therefore, also the pressure in the wheel brake of the right front wheel VR_p is higher than in the wheel brake of the left front wheel VL_p. In the example, the valve actuation signals V_{alti1} for the left front wheel 'left front' are also sent to both wheels of the rear axle V_{alti3} and V_{alti4}.

As is shown in the curves of the yaw rate, the steering angle and the wheel speeds, the vehicle remains stable in this case. Compared to the per se known ABS controlled braking operation according to the 'select-low' principle in Figure 1, the amplitude of the vehicle yaw rate (FYAWRATE) is lower so that the driver is less demanded to correct the vehicle yaw rate by way of a change in the steering angle (FSTANGLE).